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Curriculum Development for Robotics Technology Program

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Abstract

With a growing need for a more skilled workforce, providing industry-driven and employment-centric training services is an important national priority. Over 3.4 million manufacturing jobs will need to be filled across the United Sates over the next decade. The skills gap is becoming greater based on the statistics provided by the Global Robotics Technology Market: Forecast, 2014-2020 published by Research and Markets, reporting that the worldwide robotics market is forecast to grow from the 2015 level of $26.98B to $82.78B in 2020. This 11 % compounded average growth in the next five years is unprecedented. Given the anticipated growth of the robotics industry, the number of jobs that will be required to meet the demand will grow exponentially as well. The future is bright for careers in STEM fields; today, the average annual salary for a STEM worker is $33,200 higher than the average of all U.S. workers, making the need for a novel robotics credential imperative. The curriculum development explained in this paper in the area of Advanced Robotics for Manufacturing was carried out broadly in two phases: Phase I of the project focused on investigating and compiling the curricula offered by different community colleges, work force education programs in universities and other industry certificate programs in the Commonwealth of Virginia and then in other states. Phase II of this project focused on curriculum development at CCAM (Commonwealth Center for Manufacturing, VA) that improves/adds the topics, compliments and fills the gap from the data gathered in the first stage. Phase II was not only based on the data generated in Phase I, but also was informed by data gathered from industry needs and new technologies that are required in the manufacturing robotics area. The next phase include implementing the developed curriculum at Community College level and at 4-year degree colleges.

Introduction

In the area of industrial automation, educational and workforce training programs are primarily in the mechatronics and machining fields. Although manufacturing industry is quickly moving to industrial robots to improve productivity and introduce new products, the education and workforce training is lagging. This is evident from the scant current availably of programs at all levels of education and workforce development (EWD) nationwide. The Commonwealth of Virginia has no EWD programs in the robotics technology area. This project was funded by the Advanced Robotics Manufacturing (ARM) Research Institute [1] and all the requirements were related to Robotics Curriculum development.

The challenges of the development of Robotics curriculum are well explained in the classroom environment [2]. The early childhood exposure to Robotics play an important benefit in robotics technology and is discussed in [3]. There are several U.S. Department of Education statistics and information available [4-11] on workforce development in robotics, manufacturing and automation areas. These statistics clearly show there is a skill gap between industry needs and what current curriculum offers at community college levels and other levels. To fill these skill gap there is a need for industry driven curriculum development and this project reflected those issues. Driven by the program objectives, the Old Dominion University (ODU) and CCAM team developed an approach to formulate the curriculum and courses. Since the mechatronics programs are mature, the approach for this project was to piggy-back on these programs to introduce robotics technology programs into the current offerings. Mechatronics is an interdisciplinary area of engineering that combines mechanical and electrical engineering and computer science. Mechatronics forms model for this project since it is fastest growing middle skill in the advanced manufacturing industry, the machining and software can be portable and can be set up quickly and affordably, and apprentices stand to gain the most monetarily. Curriculum in Robotics Technology includes working on equipment and on software programing. It is very important that course modules and lab assignments should also focus on troubleshooting skills and maintenance methods [12,13].

Technicians trained in advanced manufacturing technologies will need to adapt their skills as automation and robotics continue to be integrated into the workplace [14] and any curriculum should reflect these. Traditional teaching techniques result in students becoming experts on specific procedures or equipment. Their expertise is attributable to experience within a specific area and they can solve similar types of problems quickly and accurately. However, routine experts have difficulty applying their knowledge to new or ill- defined problems. Surprisingly, even within their field of expertise, routine experts may only perform slightly better than novices on new types of tasks [13]; they are unable to adapt when the structures of the problem change [15]. In any new curriculum development these issues need to be addressed. The curriculum without any hands-on lab experiments does not give any weightage to it and especially in the areas of Robotics and Automation. The developed courses in the curriculum have integrated lab experiments that use equipment from well-known academic and industrial use [16,17]. One of the main objectives of this project was to choose community colleges that have an AS degree in a closely related curriculum to the Robotics area so that the developed curriculum can easily be integrated. Based on these reasons, John Tylor and South Side Virginia community colleges were chosen for this project [18,19].

Project Approach and Methodology

A multifaceted approach was designed to develop a relevant education and workforce development program. final curriculum was developed based on inputs from industry partnership, industry survey, and curricular survey. These activities were the most relevant since it informed the curricular development.

Industry Partnership: An industry partnership in the Hamptons Road area was established to get current industry needs in robotics areas. The approach was to contact high-level managers in the company and have an open-ended discussion. This allowed for follow up on issues that were of interest to this project. Most of these contacts were established through existing relationship between Old Dominion University, College of Engineering and Technology and the local industries. These meetings focused on (1). Understand their needs in automation and robotics/robotic vision, (2) The skill set gap, (3) Willingness to partner with academia to develop training programs. In most cases there were multiple engineers present beside the managers.

A total of six companies were surveyed over the summer 2018. Four companies were also visited. The site visits included a tour of the shop floor. This gave an opportunity to see first-hand the automation and robotics being used in the manufacturing process. It also gave the engineer an opportunity to articulate their needs and best practices.

Community College Programs in the Commonwealth of Virginia: Education and workforce development in industrial automation is done primarily at the community college level, or at for-profit institutions such as ECPI, leading to a Career Studies Certificate or an Associate Degree. The Career Studies Certificate is a program which does not require general education and is limited to 9-29 credit hours. These are approved by colleges locally in response to area business needs. An Associate Degree generally combines instruction in mathematics, science, and English with technical courses leading to the required competencies for entry-level and mid-level positions in business, industry, and government. Some of these programs, for example Tidewater Community College (TCC), partner with local companies to offer apprenticeship opportunities. These programs are often labeled Mechatronics, under a broader Manufacturing or Technician category. The Virginia Community College System (VCCS) lists the colleges as offering associate degrees/certificates in Mechatronics, as shown in Table 1. The students enrolled in Associate Degree programs are exposed to advanced automation through their technical electives. The Certificate Programs in most cases lead to a Siemens Certified Mechatronics Systems Assistant/Associate. All programs provide some hands-on experience in PLC and process control integration.

Table 1: Mechatronics program in the Commonwealth of Virginia

Community College	**Degree/Certificate**
Tidewater	Associate of Applied Science and Certificates
Thomas Nelson	Several Levels of Certificate programs
Paul D. Camp	Associate of Applied Science
Virginia Western	Associate Degree
Southside Virginia	Career Studies Certificate in Advanced Manufacturing Technology
John Tyler	Associate in Mechanical Engineering Technology, Mechatronics Specialization

Framework for Robotics Technology Programs

The framework for the curriculum was based on a representative Mechatronics Program at the Associate Degree Level and Industry Partners who participate in Apprentice programs. The requirements for a registered apprentice program with the Virginia Department of Labor and Industry (DOLI) is a minimum of 2,000 hours of supervised on-the-job training and a minimum of 144 hours of related technical instruction for each year of apprenticeship. Of the 23 Community Colleges in Virginia only two offers mechatronics apprenticeship which would be the closest to a robotics program. More popular apprentice programs are in machining, welding and information technology. at the Associate Degree Level and Industry Partners who participate in Apprentice programs. The following sub-sections discuss the below listed levels of programs: Associate Degree in Robotics Technology, Apprentice Program leading to Associate Degree and Journeyman in Robotics Technology, and Career Studies Certificate in Robotics Technology.

Associate Degree in Robotics Technology:

The following Table shows a layout of a typical Associate Program in Mechatronics. The outcome of this research project/paper suggested three courses that will be specific to a degree leading to Robotics. Program Duration: 2 years (4 semesters) 66 credit hours

Table 2. A layout of a typical Associate Degree Program in Mechatronics

Semester 1 General Education/Math/Science 7 AC. and D.C. Circuit Fundamentals 3 Introduction to Mechatronics 3 Semester Total 16	**Semester 2** Technical Elective 4 Hours Electric Motor Control 4 Electrical Machines 3 Digital Systems 3 Instrumentation 3 Semester Total 17
Semester 3 Technical Elective Programmable Logic Controller 3 Electronic Devices 3 Mechanical Maintenance 3 Fluid Power - Pneumatic Systems 3 Semester Total 16	**Semester 4** General Studies/Math/Science 9 Mechanisms 3 Hydraulic Systems 3 Elective 3 Semester Total 18 Total Minimum Credits 66 - 67
Electives: - Programmable Logic Controller Systems II (3 cr); - Industrial Robotics Programming (3 cr); - Microcontroller Interfacing and Programming (3 cr); - Process Control Integration (4 cr);	

Apprentice Program leading to an Associate Degree and a Journeyman in Robotics Technology usually spans a duration of (8000 Hours - 4 years): Year 1 (12 months): Introduction and short-term rotation; Year 2-3 (18 months): Long term rotation; Year 3-4: (18 months): Specialized rotations.

Career Studies Certificate in Robotics Technology:

The certificate is awarded to students who complete a career/technical education program of at least 30 credits. The challenge here is to come up with curriculum that is not too theoretical but more hands on. This will require revisiting the courses and condense it down to two. Based on the above research and input from industry members three courses were developed that can be adapted in institution with associate degrees in applied science with concentration in industrial/mechanical/electrical technology. Programs with mechatronics makes the implementation easy. This project has taken the example of John Tyler Community College with an existing Mechatronics track and Southside Virginia Community College with no Mechatronics concentration.

Credential Stacking:

As the ODU team have interacted with workforce development board in various disciplines, the idea of credential stacking is becoming popular. For example, with little or no addition credit hours, the robotics technology program based on the institution could qualify for the following certifications: OSHA certification and NIMS Credential, Festo Industry 4.0 Certification Program, and NC3 | National Coalition of Certification Centers.

Outreach Training Programs (OSHA 10-Hour & 30-Hour Cards): The 10-hour training program is primarily intended for entry level workers. The 30-hour training program is intended to provide workers with some safety responsibility and a greater depth and variety of training. All outreach training is intended to cover an overview of the hazards a worker may encounter on a job site. Training emphasizes hazard identification, avoidance, control and prevention, not OSHA standards.

NIMS: Each NIMS credential represents a collection of skills and knowledge, and a person that earns one has demonstrated competency in that occupational area. As that person earns more of these stackable credentials, they show that they are a valuable individual with an array of skills that have been verified against an industry-written standard. These are some examples of stackable credentials: Electrical, Electronic Control Systems, Maintenance Operation, Basic Pneumatic Systems, Basic Hydraulic Systems, Basic Mechanical Systems, Process Control Systems, and Machine Service and Repair.

Festo Industry 4.0 Certification Program: Provides two pathways: 1. The Institution's pathway to qualification and 2. The student's pathway to qualification.

NC3: National Coalition of Certification Centers: The certification curriculum represents a complete turn-key system of classroom presentation materials, labs, and exams centered on today's in-demand industry skills. It supplements a schools existing curriculum.

Proposed offered degree: Associate Degree in Mechanical Engineering Technology, Mechatronics and Robotics Specialization - Proposed Curriculum:

This ARM project goal was to develop courses in Robotics and Vision systems, instrumentation and motion control and industrial networking areas and add the content to either existing courses or add as elective courses at chosen/selected community college for apprenticeship program/certificate. Since one cannot add/delete any general studies section and support courses section, the only place to modify course lists to reflect our proposed changes were in core courses section. The following section details proposed curriculum at John Tyler Community College for Mechanical Engineering Technology with Mechatronics and Robotics Vision Systems specialization. After reviewing survey results, industry visits outcomes and review of JTCC existing curriculum, new curriculum design was planned and developed with three new courses so that the existing curriculum and number of credit hours for AS degree will not be affected. Figure 1 shows the block diagram of process plan of new courses development.

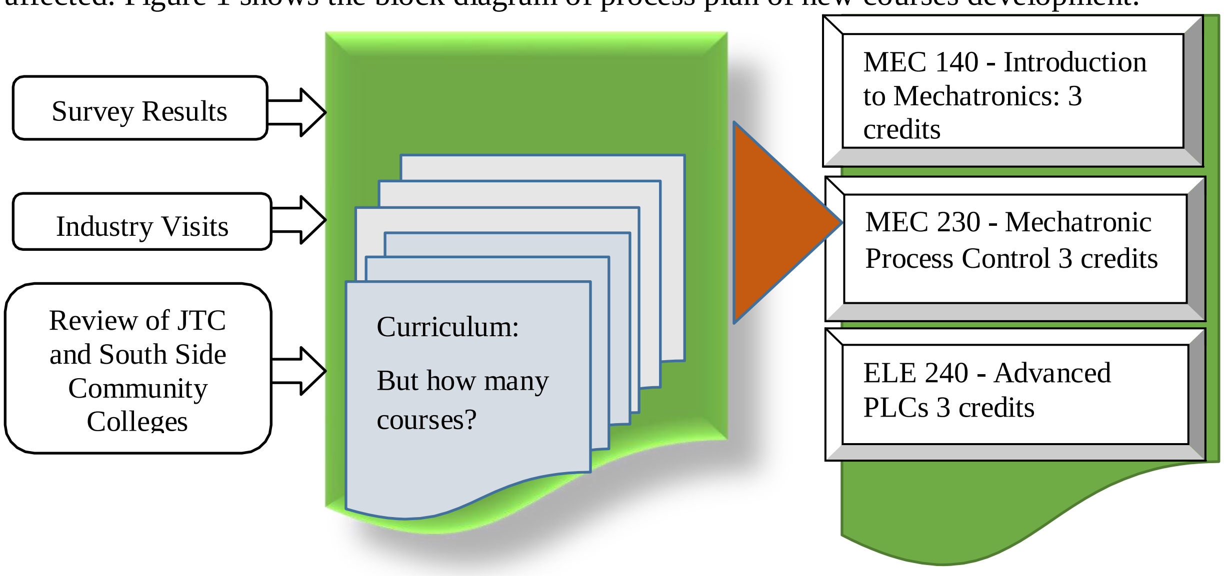


Figure 1. Process plan for new courses

The proposed new courses will be added in 3rd and 4th semesters of the curriculum. Also, these new courses will either replace the existing courses or new content will be integrated into existing courses. In the following sections, the proposed new curriculum's salient features, how the proposed curriculum is different from existing traditional curriculum and the laboratory equipment selection for the new three courses are explained. All proposed courses will have integrated Labs. They will be flexible so that content can move across the courses; same lab equipment can be used or combined in any course; the focus is system integration of Robots and Training Systems with PLCs & HMI & put them on network to mimic real time industry factory floor; same equipment can be used as standalone in short courses; content can be combined to offer few weeks certification programs, and the content/labs make students to ready for NIMS and other certifications.

As shown in Figure 2, the new courses have cross course topics and so any lab/topic in a course can easily be adopted n other course. In summary, this new curriculum provides the skills in system integration, collaborative skills from all courses and finally cross course lab equipment usage and technical topics. These features are considerably different from traditional existing curriculum.

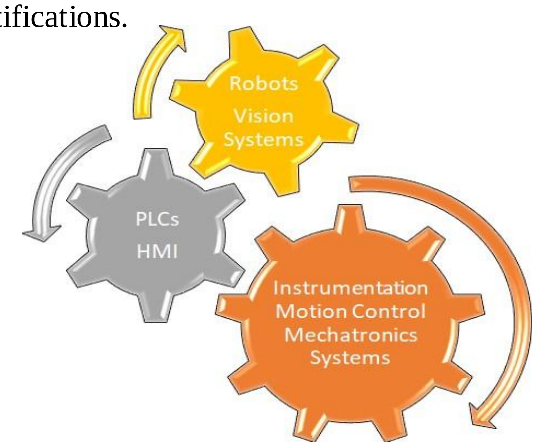
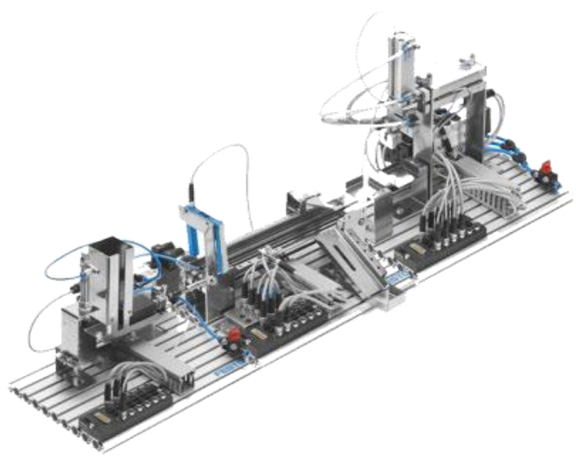


Figure 2. New courses features



Laboratory Equipment: There were multiple options for equipment for the laboratory. Based on curricula need and support available from vendors the equipment listed below were opted. The same kind of equipment will be used in lab modules for an anticipated technical elective laboratory course (Industrial Automation and Robotics Laboratory) for ODU students in the ET (Engineering Technology) and Electrical and Computer Engineering B.S. program.

Figure 3. PLC Rack with I/O Devices   Figure 4. Festo Mechatronics Training System

The following stations are now integrated in ODU Robotics lab: PLC Rack with HMI and Motor Drives, PLC Rack with I/O Devices, Festo Robot Teach Pendant with Conveyor Belt System, Festo Robot Training System, Festo Mechatronics Instrumentation system, Festo Mechatronics Training System, and Kuka Robot with Vision System, as shown in Figures 3-6. Another robot arm that is popular with educational institution is the FANUC LR Mate 200iD robots. It is to be noted that in the curriculum implementation stage, one does not have to choose exact model/vendor instead this curriculum provides necessary requirements for lab exercises. All proposed new courses have integrated Laboratory part, the assessment for each course is combined with lab exercises.

Figure 5. Festo Robot Training System

Figure 6: Kuka Robot with Vision System

Conclusions and Future Work

The main objective of this work was to develop the curriculum in Robotics Technology Program at the Associate Degree level with minimally impacting existing curriculum in existing AS degree programs. The industry needs and the skills gaps were established at the beginning of the project followed by the current status of EWD effort nationwide and in the commonwealth of Virginia. This formed the basis for the framework for curriculum and course development to bridge the skills gap. The involvement of the two community colleges in the south side and their feedback as the curriculum was being developed was very helpful. Meetings with mid-size industry in the Hampton Roads area to survey their needs and skill gap were invaluablet inputs in developing the designed curriculum. Also, an industry survey was completed on site at CCAM on the Additive Manufacturing Research Day that played an important role in formulating some modules in the developed curriculum. The main project outcomes include, Industry Surveys, Curricular Surveys and in the curriculum section, course modules with integrated laboratory modules were developed. From interaction with community colleges it is apparent that each program will need customization. The most relevant and realistic future work for this project will be implementation at community colleges with existing mechatronics program and an industry base to support apprenticeship.

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